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# Modeling the Determinants of Pedestrian Access to BART

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# MODELING THE DETERMINANTS OF PEDESTRIAN ACCESS TO BART:

## A BART @ 20 Report

## I. Introduction

Practically all motorized trips — whether from home to office, from a car into a store, or from a plane to a taxi to a ski slope — begin or end by walking. Although sometimes a "line-haul" mode, walking is more commonly an access mode to, or an egress mode from, another mode. Despite its importance, walking has long been a relatively understudied mode of transportation.

This paper examines the role and determinants of walking as a transit access mode. The conventional wisdom is that the only determinant that matters is walking distance; commuters will walk a maximum of 1/4 to 3/8 of a mile from their home to a transit stop, but no farther. But is distance the only factor that matters? What about the convenience of walking, or the enjoyment associated with walking? And how important are demographics? Are younger transit riders more likely to walk than older ones? Are women less likely to walk than men?

We hypothesize that the choice of transit access mode — and in particular, the decision whether or not to walk — is a function of four sets of factors: (i) the demographic characteristics of the individual traveler; (ii) the time and cost associated with walking relative to other access modes; (iii) the convenience of walking (again, relative to other modes); and (iv) the enjoyment associated with walking—which may or may not be related to the physical character of the walking environment. This paper presents a series of statistical models which test this hypothesis using sample data collected as part of a 1992 survey of riders of the Bay Area Rapid Transit (BART) system. BART provides an especially good framework for this type of study because of the diversity of station types and access mode choices.

The question of why and how far transit riders will walk has both planning and research implications. One of the current challenges facing BART planners is how best to design new stations (and/or redevelop older ones) to maximize BART patronage without building parking facilities. One way of meeting this challenge is to encourage the development of pedestrian-friendly land uses adjacent to BART stations. These uses include offices, retail, and especially housing. Looking further into the future, the long-term feasibility of BART may very much depend on the extent to which particular BART stations become regional activity nodes. One way to generate these nodes may be to encourage the development of a diverse mixture of pedestrian-accessible land uses.

The remainder of this paper is organized into six sections. Part Two reviews the available literature on the popularity and determinants of walking as a transit access mode. Part Three summarizes the results of the 1992 BART Passenger Profile survey, paying special attention to the mix of access and egress modes. Part Four develops the first of two sets of traveler-based statistical models of BART station access mode choice. Part Five expands the statistical modeling framework to incorporate nearby land use and urban design factors. Part Six combines the two statistical modeling approaches, and Part Seven summarizes the results of the analysis, and explores their generalizability and implications for BART system planning.

## II. Literature Review: Why Walk to Transit?

The role of walking as a transit access mode varies by city and transit system. Comparing five different transit systems, including BART, Replogle (1992) found that pedestrian access trips accounted for as little as 38% of light-rail transit access trips in Sacramento, to as much as 72% of bus access trips in Columbus, Ohio. BART was toward the lower end of this distribution, with walking accounting for only 48% of access trips in 1987.

Table 1: Walk Access Mode Share - Selected Rail and Bus Systems

| *City* | *System* | *Mode Share* |
|---|---|---|
| BART | Rail | 48.1% |
| Sacramento | Light-rail | 38.0% |
| Sacramento | Bus | 68.0% |
| Columbus, OH | Bus | 71.7% |
| Detroit | Bus | 68.7% |

Source: Replogle, 1992

### *Why Transit Riders Walk:*

Ridership surveys indicate the key role that distance plays in walking decisions. More than 80% of respondents to a 1989 Metro ridership survey conducted by the Washington Council of Governments identified excessive walking distance as their primary reason for not walking to a Metro station. Danger from auto traffic, the next most important deterrent, was identified by only 28% of respondents. Summarizing the results of several pedestrian access surveys, Zehnpfenning (1993) also identified excessive distance as the single most important deterrent to walking.

A different survey of walkers in Edinburgh, Scotland by Hine and Russell (1993) identified area traffic conditions and the difficulty of cross roads as the most common of pedestrian concerns. Slowing down or even eliminating motor vehicle traffic, they concluded, would significantly boost pedestrian activity. Multiple surveys undertaken by the Project for Public Spaces (1993) have identified other pro-pedestrian urban design practices, including (i) balancing street space and uses; (ii) provision of

pedestrian amenities; (iii) development of improved orientation, signage, and circulation systems; and (iv) providing enhanced security.

Another approach has been to observe where and when people walk and to draw conclusions accordingly. In a 1975 study of Chicago area transit users, Lee observed that only 1 in 21 transit riders was willing to walk more than 1/2 mile to a transit station. Strigham (1982), in separate research, found that transit riders would walk longer distances for better service, but practically no one would walk more than 4,000 feet. Unterman (1984) identified 2,300 feet or 10 minutes to be the maximum distance or time that Americans would walk to transit. Europeans, however, were willing to walk longer distances. Fruin (1992) concluded that while 1/2 mile (or 10 minutes) was typically the longest walking distance to transit, many pedestrians were willing to walk longer distances if they could be guaranteed high-quality transit service.

A third approach relies on statistical models to identify different determinants of access mode choice. Using data from a 1975 survey of BART riders, Korf and Demetsky (1980) found that the decision of whether to walk to the nearest BART stations rested on only two factors — distance and auto availability.

A number of recent studies have focused on the relationship between transit use and urban form. Ewing et al. (1993) and Friedman et al. (1992) observed significant differences in transit use and travel behavior between older, traditional neighborhoods and newer, auto-dependent neighborhoods. Cervero (1993) compared travel behavior between matched pairs of transit-oriented and auto-oriented neighborhoods in the San Francisco and Los Angeles areas. While there was no difference in auto use for non-work trips between the two neighborhood types, work trip walk mode shares were significantly higher in the transit-oriented neighborhoods. Handy (1995) used a similar matched-pair method to analyze walk mode shares for utility and recreational trips. She found urban form — particularly as it affected walking distances — to be a significant determinant of walk mode choice, but not as important as individual characteristics. In related research, Shriver (1996) counted more frequent walking and utility trips in accessible, compact neighborhoods than in suburban ones.

Frank and Pivo (1994) used census data to examine the effects of density and land use on mode shares. At the level of the census tract, walk mode shares (for all trips) were found to be highly sensitive to population density and less sensitive to land use mix. The positive effect of density on walking was found to vary between work trips and shopping trips.

Taking still a different approach, researchers at Cambridge Systematics (1994) combined survey and statistical analysis to explore the relative effectiveness of pricing versus land use strategies in reducing work-trip auto use in Los Angeles mode shares. Although pricing was found to be the single most effective approach to reducing auto use, pricing combined with pedestrian and transit-supportive land use policies were found to be more effective than pricing alone.

### III. Walk Access and Egress Trips to BART[1]

Bay Area travelers undertook an average of 240,000 BART trips[2] every day in 1992. Because most BART origin and return trips follow the same route, the choice of access mode for the origin BART trip usually determines the choice of egress mode for the return BART trip.

Auto trips accounted for 44% of all BART access trips in 1992, followed by walk trips (33.5%), other transit modes (20.5%), bicycle trips (1%), and taxi trips (0.5%) according to the results of BART's 1992 passenger profile survey[3]. Both the number and share of walk access trips in 1992 were down from 1987 levels even though total BART ridership was up (Figure 1).

As Figure 2 shows, access and egress mode shares vary by trip purpose. Walking, for example, accounted for only 23.7% of home-based BART access trips in 1992, about the same percentage as other transit modes (principally bus: 23.8%), but far less than private automobiles (51.2%). At the destination end of a home-based BART trip, walking accounted for more than three-quarters of all egress trips. For non-home-based (or return BART trips), walking accounted for 71.8% of access trips, followed by transit (16.2%), and driving (10.7%).

For the destination end of non-home-based BART trips, driving accounted for 53.6% of egress trips, followed by walking (31.0%) and other transit modes (24%). Bicycling accounted for about one percent of all access and egress trips regardless of origin or purpose. These differences reflect the fact that the private car is the primary mode of access for the morning work trip while walking is the primary egress mode. This situation is reversed for the return trip where walking becomes the primary access mode and the car becomes the primary egress mode.

Although the car is the access mode of choice at most BART stations, as Table 2 shows, there is a surprising amount of station-to-station variation in access mode shares.

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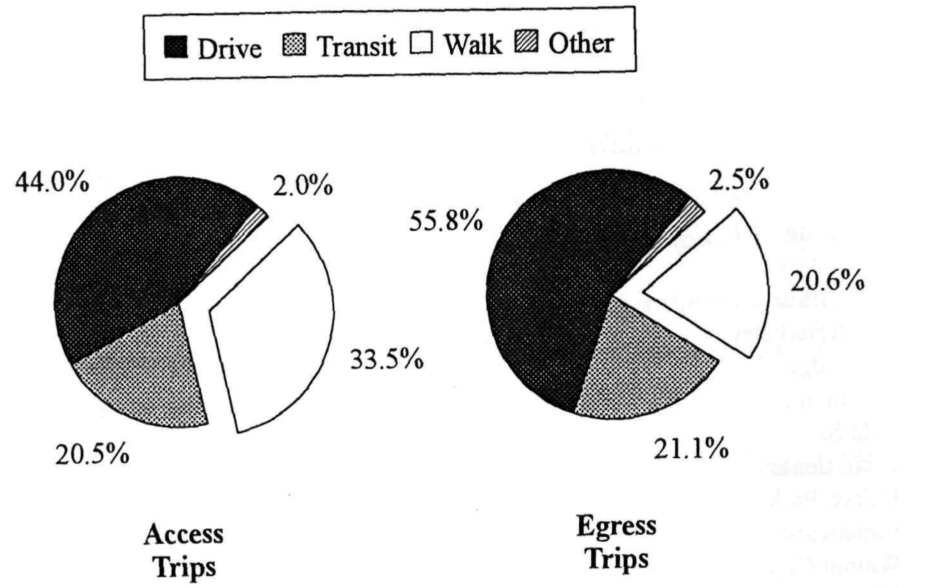
[1] BART provides an especially appropriate case study for analyzing walk access trips. BART is a combination of suburban commuter railroad and downtown subway. BART's 34 stations include 18 suburban stations with significant parking facilities, 8 downtown stations, and 8 urban residential stations. Local bus service is available to almost all BART stations, and the four downtown San Francisco stations are also served by a light-rail system. Most BART stations include kiss-and-ride facilities.

[2] BART planners define a trip as a one-way trip. A home-to-work-to-home round-trip is considered by BART planners to consist of two separate trips.

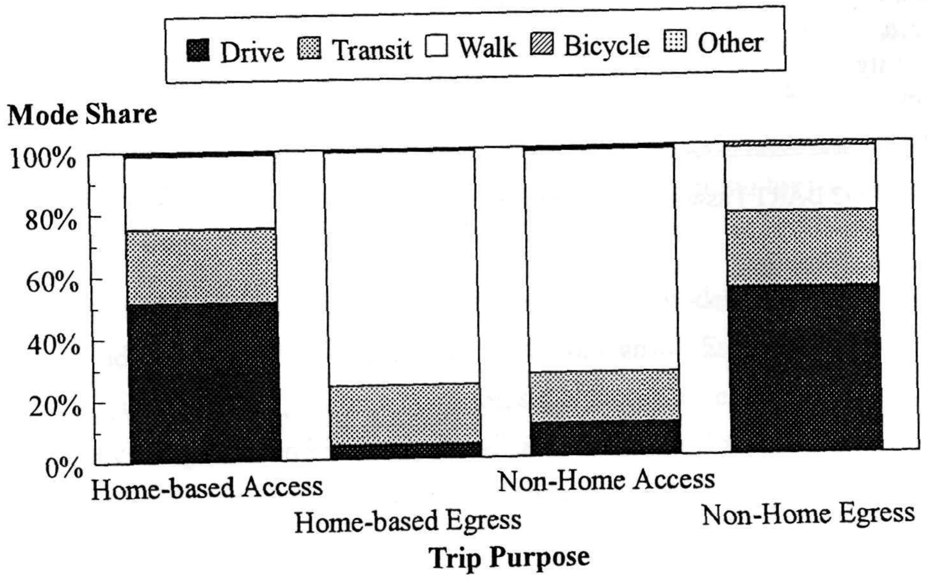
[3] BART planners conducted large-scale passenger surveys in 1975, 1982, 1987, and 1992. The 1992 survey generated nearly 34,000 responses; it included information on each rider's trip origin and destination, station of origin and destination, mode of access, trip purpose, fare paid and method of fare payment, and various demographic data.

Figure 1: BART Access and Egress Mode Shares



*Source: 1992 BART Ridership Survey*

Figure 2: BART Access and Egress Mode Shares by Trip Purpose



*Source: 1992 BART Ridership Survey*

**Table 2: Access Mode Shares by BART Station, 1992**

| | Access Mode Share | | | |
|---|---|---|---|---|
| **BART Station** | Walk | Car | Transit | Other |
| 16th & Mission | 74.2% | 9.2% | 15.7% | 1.0% |
| 24th & Mission | 67.2 | 8.3 | 23.4 | 1.1 |
| Berkeley | 54.2 | 21.6 | 21.1 | 3.1 |
| 19th St. | 43.5 | 30.1 | 25.3 | 1.1 |
| Ashby | 41.0 | 49.8 | 6.6 | 2.6 |
| Glen Park | 40.6 | 30.9 | 28.0 | 0.6 |
| Powell | 37.9 | 11.9 | 49.3 | 0.9 |
| El Cerrito | 31.7 | 56.6 | 10.5 | 1.1 |
| Lake Merritt | 31.5 | 43.8 | 22.4 | 2.3 |
| MacArthur | 29.6 | 49.9 | 17.7 | 2.9 |
| North Berkeley | 28.4 | 62.6 | 5.8 | 3.2 |
| Rockridge | 27.7 | 60.9 | 8.9 | 2.5 |
| Richmond | 25.0 | 48.9 | 24.3 | 1.8 |
| 12th St. | 22.0 | 18.9 | 57.1 | 2.0 |
| Civic Center | 20.9 | 13.9 | 62.5 | 2.8 |
| Balboa Park | 19.2 | 32.1 | 48.3 | 0.4 |
| Embarcadero | 18.7 | 8.3 | 68.9 | 4.1 |
| Walnut Creek | 17.9 | 56.5 | 24.0 | 1.6 |
| Montgomery | 16.0 | 6.6 | 76.6 | 0.8 |
| West Oakland | 14.8 | 74.0 | 11.2 | 0.0 |
| El Cerrito del Norte | 14.1 | 64.0 | 21.4 | 0.4 |
| San Leandro | 14.1 | 67.1 | 17.5 | 1.3 |
| Coliseum | 13.4 | 51.0 | 34.8 | 0.8 |
| Bayfair | 12.0 | 67.8 | 19.0 | 1.1 |
| Daly City | 11.1 | 60.0 | 28.2 | 0.7 |
| Lafayette | 10.8 | 81.5 | 6.8 | 0.9 |
| Pleasant Hill | 10.7 | 79.3 | 8.9 | 1.1 |
| South Hayward | 10.7 | 76.9 | 12.0 | 0.4 |
| Fruitvale | 9.9 | 63.1 | 25.4 | 1.7 |
| Hayward | 8.9 | 71.6 | 19.2 | 0.2 |
| Concord | 8.8 | 70.5 | 18.6 | 2.1 |
| Union City | 8.8 | 74.6 | 16.1 | 0.6 |
| Fremont | 3.9 | 84.5 | 11.3 | 0.3 |
| Orinda | 2.8 | 90.7 | 5.9 | 0.6 |

Source: 1992 BART Passenger Profile Survey

Walk trips account for the majority of home-based access trips only at the 16th and Mission, 24th and Mission, and downtown Berkeley BART stations. Walk trips are the dominant access (although not majority) mode at the Ashby BART station in Berkeley, at the 19th Street station in Oakland, and at the Glen Park and Powell Street BART stations in San Francisco.

- At the opposite end of the spectrum, walk trips accounted for less than 10% percent of home-based BART access trips at the Orinda, Fremont, Concord, Union City, Hayward, and Fruitvale BART stations. All six of these stations are surrounded by large parking lots, making walking somewhat less convenient. Four are surrounded by fairly low-density development.
- Transit (bus and MUNI, the San Francisco Municipal Railway) is the majority of modes of access (for home-based trips) at the Civic Center, Montgomery, Embarcadero, Oakland 19th Street, Powell, and Balboa Park BART stations.
- Taxis and bicycling typically account for less than two percent of home-based BART access trips.

## IV. Modeling BART Access Mode Choice

Why do some BART patrons walk to BART, as opposed to driving, bicycling, or taking the bus? This part and the two that follow develop a series of statistical models to answer this question. The models developed in this chapter utilize a discrete choice framework to explore the effects of individual demographic and trip characteristics on transit access mode choice decisions. A second set of models, developed in Part V, examines the effects of station area characteristics (including urban form/design characteristics) on transit access mode share. Linear regression is used to isolate the contribution of particular physical design factors and to control for the effects of station area demographic characteristics. A final analysis, presented in Part VI, again uses a discrete choice framework to combine the individual mode choice results from Part IV with the station area mode share results of Part V. Bringing the two sets of variable types together in this fashion provides a clearer understanding of the role of urban form and physical design by controlling for the individual characteristics of BART users.

BART users can choose from a number of different access modes: walking, driving alone, carpooling, kiss-and-ride, bicycling, taxis, and other modes of transit. Each traveler makes his or her own access mode decision, based in part on a common set of factors or characteristics. These include personal attributes, such as gender and income; as well as the characteristics of the access trip itself, including distance, time, cost, and the availability of alternative modes.

Transportation planners commonly use logistic (or logit) models to study the determinants of discrete choices. Binomial logit models are used to compare two choices; multi-nomial logit models are used to compare three or more choices. Conditional choices can be represented as a series of hierarchical, or "nested" binomial choices.

As suggested above, we hypothesize that the choice of BART access mode is a function of the characteristics of the traveler, the characteristics of the access trip, and the availability of alternative access modes (Equation 1). As with all logit models, the dependent variable is expressed as a probability – in this case, the probability that a traveler will choose to walk:

$$\textbf{Eq.1:}\quad \text{Prob [Traveler}_i\text{: Walking]} = \text{f[Demographics}_i\text{, Trip Characteristics, Availability of Alternative Modes]}$$

Information on all of these characteristics, including choice of access mode, was collected by BART in its 1992 Passenger Profile Survey. All of the models that follow are limited to the home-based origin subset of this database. This subset includes 12,398 of the nearly 34,000 total responses and is the largest single-purpose subset. Table 3 lists the means and frequencies of the variables drawn from that survey. Note that except for *DISTANCE* (measured distance to nearest BART station) and *OBLOCKS* and *DBLOCKS* (blocks walked to and from BART, respectively), all of the included variables are either nominal or ordinal.

### *The Role of Traveler and Trip Characteristics in BART Access Mode Choice*

Three separate binomial logit models of BART access mode choice were tested. The first compares walking with all non-walking access modes combined (including transit, automobile, bicycle, motorcycle, and taxi); the second compares walking solely to transit access modes; and the third compares walking with auto access modes. The results of all three models are presented in Table 4. In terms of goodness-of-fit, the model comparing walk access to other transit modes performed best, correctly predicting 92% of walk trips and 70% of transit access trips. The walk/non-walk model, by comparison, correctly predicted only 58% of walk access trips, and 94% of non-walk access trips. The performance of the walk/drive model was about midway between the walk/transit and the walk/non-walk models. Parameter estimates are reported for each included variable, regardless of their statistical significance. Variable significance is assessed at the 90% probability level.

Three independent variables were statistically significant across all three models: walking distance, gender, and car availability. Distance, as expected, has a negative effect on walking preferences; the greater the distance the traveler must walk to the nearest BART station, the less likely he or she is to do so. Women comprise the majority (53.5%) of BART patrons, but are much less likely than men to

## Table 3: Variable Descriptions and Summary Statistics

| **Variable** | | **Frequency** | **% of Total** |
|---|---|---|---|
| *BART Access Mode* | | | |
| Walk | WALK-ACCESS | 2,731 | 23.7% |
| Transit | TRANSIT-ACCESS | 2,657 | 23.0 |
| Auto | AUTO-ACCESS | 5,925 | 51.3 |
| All Non-walk | NONWALK-ACCESS | 8,815 | 76.3 |
| *BART Egress Mode* | | | |
| Walk | WALK-EGRESS | 9,280 | 75.5 |
| Auto | AUTO-EGRESS | 547 | 4.5 |
| Transit | TRANSIT-EGRESS | 2,362 | 19.2 |
| Bicycle | BIKE-EGRESS | 63 | 0.5 |
| *Trip Purpose* | | | |
| Home | PURHOME | 392 | 3.2 |
| Work | PURWORK | 9,348 | 76.4 |
| School | PURSCHL | 1,005 | 8.2 |
| Shopping | PURSHOP | 151 | 1.2 |
| *Alternative Mode Availability* | | | |
| Car available for access trip? | CARAVAIL (Yes/No) | 6,342 | 53 |
| Transit available for access trip? | TRANAVAIL (Yes/No) | 7,112 | 57.4 |
| *Traveler Characteristics* | | | |
| White ethnic | EWHITE | 7,477 | 60.3 |
| Black ethnic | EBLACK | 1,561 | 12.6 |
| Asian and Pacific Islander indicator | EASIAN | 1,829 | 14.8 |
| Gender (given in % male) | GENDER | 5,656 | 46.5 |
| Age 12 or younger | AGE0 | 59 | 0.5 |
| Age 13 to 17 | AGE13 | 153 | 1.2 |
| Age 18 to 24 | AGE18 | 1,282 | 10.3 |
| Age 25 to 34 | AGE25 | 3,571 | 28.8 |
| Age 35 to 44 | AGE35 | 3,586 | 28.9 |
| Age 45 to 64 | AGE45 | 3,023 | 24.4 |
| Age 65 and older | AGE65 | 499 | 4 |
| Household income $15,000 or less | INC0 | 1,307 | 2.6 |
| Household income $15,001 to $30,000 | INC15 | 2,314 | 19.9 |
| Household income $30,001 to $45,000 | INC30 | 2,424 | 20.8 |
| Household income $45,001 to $60,000 | INC45 | 2,033 | 17.4 |
| Household income $60,001 to $75,000 | INC60 | 1,355 | 11.6 |
| Household income $75,001+ | INC75 | 2,223 | 19.1 |
| *Walk Distance* | | Mean | Std. Dev. |
| Computed straight line distance to BART station | DISTANCE | 2.7 | 4.3 |
| Blocks walked to BART | OBLOCKS | 1.4 | 4.3 |
| Blocks walked from BART | DBLOCKS | 2.5 | 5.9 |

Source: 1992 BART Passenger Profile Survey

## Table 4: Results of Three BART Access Mode Choice Models

| Independent Variable | Walk vs. Non-Walk Model Coefficient | Walk vs. Non-Walk Model Significance level | Walk vs. Transit Model Coefficient | Walk vs. Transit Model Significance level | Walk vs. Auto Model Coefficient | Walk vs. Auto Model Significance level |
|---|---|---|---|---|---|---|
| DISTANCE | -1.5373 | 0.0001 | -1.0697 | 0.0001 | -1.3012 | 0.0001 |
| DBLOCKS | 0.0139 | 0.0023 | 0.0242 | 0.0013 | 0.008 | Not significant |
| WALK-EGRESS | -0.2081 | Not significant | -0.1084 | Not significant | -0.3835 | Not significant |
| BIKE-EGRESS | -0.2081 | Not significant | -0.4152 | Not significant | 0.003 | Not significant |
| AUTO-EGRESS | 0.0795 | Not significant | 0.1226 | Not significant | 0.0128 | Not significant |
| TRANSIT-EGRESS | -0.0017 | Not significant | -0.0712 | Not significant | -0.0928 | Not significant |
| PURHOME | 0.1861 | Not significant | 0.1429 | Not significant | 0.4519 | 0.0357 |
| PURWORK | -0.2513 | 0.0037 | -0.2051 | 0.047 | -0.3566 | 0.0005 |
| PURSCHL | -0.2793 | 0.0183 | -0.2519 | 0.0679 | -0.2732 | 0.0574 |
| PURSHOP | 0.1399 | Not significant | 0.0848 | Not significant | 0.4243 | 0.0589 |
| CARAVAIL | -0.5331 | 0.0001 | 0.116 | 0.0941 | -1.0059 | 0.0001 |
| TRANSAVAIL | 0.2836 | 0.0001 | 0.1498 | 0.0266 | 0.4204 | 0.0001 |
| EWHITE | 0.0896 | Not significant | 0.1487 | Not significant | 0.0066 | Not significant |
| EBLACK | -0.3835 | 0.0002 | -0.3714 | 0.0018 | -0.4245 | 0.0005 |
| EASIAN | -0.2936 | 0.004 | -0.4126 | 0.0005 | -0.2327 | 0.0522 |
| GENDER | 0.4713 | 0.0001 | 0.3531 | 0.0001 | 0.6064 | 0.0001 |
| AGE13 | 0.1406 | Not significant | -0.0652 | Not significant | 0.6483 | Not significant |
| AGE18 | 0.2414 | Not significant | 0.5089 | 0.0548 | 0.0739 | Not significant |
| AGE25 | -0.0043 | Not significant | 0.2486 | Not significant | -0.1469 | Not significant |
| AGE35 | -0.2405 | Not significant | 0.0757 | Not significant | -0.3888 | Not significant |
| AGE45 | -0.4239 | 0.0698 | -0.1104 | Not significant | -0.6211 | 0.0302 |
| AGE65 | -1.0226 | 0.0003 | -0.8302 | 0.0072 | -1.2778 | 0.0001 |
| INC15 | 0.0953 | Not significant | 0.0551 | Not significant | 0.0497 | Not significant |
| INC30 | -0.0325 | Not significant | 0.1784 | 0.079 | -0.315 | 0.0021 |
| INC45 | -0.1769 | 0.0626 | 0.1268 | Not significant | -0.5276 | 0.0001 |
| INC60 | -0.3349 | 0.0027 | 0.0595 | Not significant | -0.7975 | 0.0001 |
| INC75 | -0.4745 | 0.0001 | 0.0462 | Not significant | -0.929 | 0.0001 |
| Constant | 1.0463 | 0.002 | 0.8962 | 0.0216 | 2.141 | 0.0001 |
| % correctly predicted | 58.0% | 94.4% | 91.8% | 69.9% | 74.3% | 91.2% |

walk to BART. We hypothesize that women tend to be more concerned about safety issues than men, particularly during early morning and evening hours. Car availability — no surprise — is a strong deterrent to walking to BART, particularly among those for whom the alternative access mode was driving. Interestingly, among those who chose transit over walking, car availability did not factor negatively into their decision to walk. Not surprisingly, the availability of transit service also serves to increase the likelihood that one will use it.

Specific age and ethnic group variables were frequently significant, depending on the model. Ethnicity is a surprising determinant of the choice to walk. Blacks and Asians are uniformly less likely to walk to a BART station than to take another mode; Asians in particular are more likely to prefer transit over walking. Blacks are more likely to prefer driving over walking. Blacks and Asians comprise approximately 25% of BART users. Except for those over 65, traveler age does not seem to consistently affect access mode preference. As might be expected, BART riders over 65 are less likely to walk to a station than younger riders.

The survey respondents included a relatively even distribution of traveler incomes with the exception of the lowest income bracket. Riders with incomes below $15,000 comprised less than 3% of the respondents. The model results suggest that income has a negative effect on the choice to walk, particularly when driving is the alternative access mode, and particularly among those with incomes in excess of $45,000. Among those for whom transit is the alternative access mode to walking, walking is more popular among those with incomes between $30,000 and $45,000.

The choice of egress mode (at the destination of a BART trip) has no effect on the choice of access mode. We hypothesize that the availability of different egress modes probably does however effect the choice whether or not to use BART for the line-haul portion of a trip. In contrast to egress mode, destination purpose does play a role in determining access mode choice.

### *Station Contributions to Access Mode Choice*

Walk preferences vary widely by BART station as well as according to the types of factors listed above. Some BART stations, by virtue of their location and design, are more amenable to walk access trips than others. Two additional sets of logit models were developed to evaluate the effects of each station on access mode choice. The first set — the results of which are shown in Table 5 — represents each BART station as its own dummy variable. If a traveler accessed BART at a particular station, the dummy variable for that station is assigned a value of one; if a traveler used another station, the assigned value is zero . A second set of models — shown in Table 6 — consists of separate logit models for each station.

## Table 5: Logit Model of BART Access Mode Choice, including BART Station Dummy Variables

| Variable | Walk vs. Non-Walk Model Coefficient | Walk vs. Non-Walk Model Significance |
|---|---|---|
| *Trip and Traveler Characteristics* | | |
| DISTANCE | -1.2966 | 0.0001 |
| DBLOCKS | 0.0131 | 0.0082 |
| PURWORK | -0.2279 | 0.011 |
| PURSCHL | -0.3298 | 0.0072 |
| CARAVAIL | -0.4483 | 0.0001 |
| EBLACK | -0.2906 | 0.0083 |
| EASIAN | -0.2636 | 0.0136 |
| GENDER | 0.4637 | 0.0001 |
| AGE65 | -0.8767 | 0.0024 |
| INC60 | -0.2505 | 0.032 |
| INC75 | -0.477 | 0.0001 |
| *BART Station Dummy Variables* | | |
| 16th & Mission | 1.4257 | 0.0001 |
| 24th & Mission | 1.1237 | 0.0001 |
| Berkeley | 1.1099 | 0.0001 |
| 19th St. | 0.9143 | 0.0001 |
| Powell | 0.8132 | 0.0006 |
| West Oakland | 0.6024 | 0.0496 |
| Glen Park | 0.4975 | 0.0078 |
| Lake Merritt | 0.432 | 0.0608 |
| Ashby | 0.4191 | 0.0485 |
| El Cerrito | 0.4066 | 0.0442 |
| Balboa Park | -0.402 | 0.0471 |
| San Leandro | -0.5305 | 0.0182 |
| South Hayward | -0.6063 | 0.0313 |
| Hayward | -0.6325 | 0.0105 |
| Fruitvale | -0.8605 | 0.0004 |
| Fremont | -0.9044 | 0.0046 |
| Orinda | -1.1886 | 0.0025 |
| Constant | 0.76 | 0.0497 |
| % correctly predicted | 58.7% | 93.9% |

## Table 6: Walk vs. Non-Walk Access Mode Choice Model Results for Individual BART Stations

| BART Station | % walk-trips correctly predicted | Independent Variable (entered only if statistically significant at the .95 level) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Walk Distance | Trip Purpose | | Car Availability | Gender (Male = 1) | Ethnicity | | | Household Income | | | | |
| | | | School | Work | | | Asian | Black | White | $15-30k | $30-45k | $45-60k | $60-75k | $75k+ |
| 16th & Mission | 97.2% | -1.127 | | | | | | | | | | | | -0.964 |
| 24th & Mission | 94.3 | -1.484 | | | | | | | | 0.731 | 0.624 | 0.63 | 1.089 | |
| West Oakland | 91.2 | -2.086 | | | -3.263 | 1.435 | | -2.8 | | | | | | |
| Pleasant Hill | 86 | -4.522 | | | -0.979 | | | | | | 2.211 | | | |
| Orinda | 77.8 | | | | | | | | | | | | | |
| Daly City | 77.8 | -3.607 | 1.922 | | -0.846 | | | -1.885 | | | | | | |
| Berkeley | 77.7 | -1.783 | | | | 0.596 | | | | | | | | |
| Glen Park | 76.9 | -2.747 | | | | | | | 0.804 | | | | | |
| North Berkeley | 74.4 | -3.538 | | | -1.169 | 1.202 | -1.862 | -1.96 | -1.11 | | | | | |
| Ashby | 72.9 | -1.328 | | -1.034 | -1.093 | 1.04 | | -1.594 | | | | | | |
| 19th St.- Oakland | 72.7 | -0.4 | | -0.921 | | 0.762 | | | | -1.007 | -1.176 | | -1.482 | -2.415 |
| El Cerrito Plaza | 71.5 | -2.28 | | | -1.201 | | | | | | | 1.249 | | |
| MacArthur | 69.5 | -2.86 | | -0.994 | -0.743 | | | | | | | | | |
| Lafayette | 69.4 | -2.374 | | | | | | | | | | | | |
| Richmond | 66.7 | -2.734 | | | | | | | | | | | -1.916 | |
| South Hayward | 66.7 | -4.035 | | | | 2.196 | | | | | | -2.77 | | -2.594 |
| Rockridge | 66.7 | -2.053 | | | | 0.903 | | | | | | | | |
| Lake Merritt | 65.7 | -1.431 | | | | 0.932 | | | | | | | | |
| Bayfair | 63.9 | -3.859 | | | -1.294 | 2.206 | | 1.994 | 1.616 | | | | | -2.969 |
| San Leandro | 60.8 | -3.075 | | | | 0.883 | | | | -1.17 | | -1.398 | -1.732 | |
| Embarcadero | 60.6 | -2.223 | | | | | -2.896 | -3.358 | | | | | | |
| Powell | 58.5 | -0.159 | -0.925 | | | | | | | | | -1.613 | | |
| Union City | 53.3 | -2.368 | | | -2.016 | | -3.054 | -3.676 | -3.3 | | 1.744 | | | |
| Fruitvale | 51.4 | -2.562 | | | -1.608 | 0.917 | | | | | | | | |
| Montgomery | 50 | -0.952 | | -1.201 | | | | | | | | | | |
| Balboa Park | 43 | -1.658 | | | -0.645 | 0.63 | | | | 0.866 | | | | |
| El Cerrito del Norte | 39 | -1.184 | 1.411 | | -0.943 | 0.751 | | | | | | | | |
| Walnut Creek | 37.7 | -1.017 | | | | | | | | | | -1.811 | | -2.411 |
| 12th St.-Oakland | 30 | -0.623 | | | | 1.012 | | | | 0.904 | | | | |
| Coliseum | 23.3 | -0.451 | | -0.991 | -1.316 | 1.328 | 2.553 | | | | -1.298 | | | |
| Concord | 18.9 | -0.889 | | -1.06 | | | | | | | | | | |
| Civic Center | 11.4 | | | | | 0.876 | | | | | | -1.587 | | -1.081 |
| Hayward | 8.6 | -0.769 | | | -1.363 | | | | | | | -1.616 | | |
| Fremont | 0 | | | | -1.252 | 1.598 | -1.899 | | | | | | | |

Adding station area dummy variables to the binomial walk/non-walk logit model developed above improves its overall predictive power only slightly — generally by less than one percent (Table 5 coefficient estimates that were not statistically significant are not listed). This suggests that station area characteristics are far less important than trip and personal characteristics in explaining the choice of BART access mode. This general result notwithstanding, several station area dummy variables were found to be statistically significant. Comparing walk to non-walk trips, the dummy variables indicating the 16th & Mission, 19th Street Oakland, 24th & Mission, Ashby, Berkeley, El Cerrito, Glen Park, Lake Merritt, Powell Street, and West Oakland, were found to be *positive* and significant. What this means is that BART riders were more likely to walk to these stations than to choose another access mode, holding constant personal and trip characteristics. Comparing walk-to non-walk trips, the dummy variables indicating the Balboa Park, Fremont, Fruitvale, Hayward, Orinda, San Leandro, and South Hayward BART stations were found to be *negative* and significant; for a variety of reasons, trip-makers preferred not to walk to these stations.

Table 6 presents the results of the binomial walk/non-walk logit model for each BART station (coefficient estimates that are not statistically significant are not listed). Given that walk access mode shares vary so widely between stations, it is not surprising that the model results also vary widely. The models for the 16th and Mission, 24th and Mission, and West Oakland BART stations, for example, correctly predict walk trip choices 90% or more of the time. At the opposite end of the goodness-of-fit spectrum, the same specification applied to the Fremont, Hayward, Civic Center, and Concord BART stations correctly predict walk trip choices less than 20% of the time. The other 27 stations fall between these two extremes.

Comparing the independent variables, walk-trip distance was found to be negative and statistically significant for all but the Civic Center and Fremont BART station. Distance effects were less pronounced among downtown stations and more pronounced among suburban station areas[4], indicating that downtown stations are generally more conducive to walking than suburban stations.

Turning to the other independent variables, gender and car availability were statistically significant at a majority of the stations. Gender was found to be consistently positive, suggesting that regardless of station, men are more likely than women to walk to BART. Car availability was found to have a consistently negative effect on the likelihood of walking to BART.

The direction and importance of the traveler's ethnicity, income, and work destination as a determinant of BART access mode varied widely by station. Except for the 24th and Mission station, upper-income travelers were less likely to walk to BART than middle- or lower-income travelers. Other personal and trip characteristics (age, school and shopping destinations, and transit availability) were rarely significant.

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[4] Concord is an exception in Contra Costa County. The Concord station is within walking distance to the downtown, which is traditional in layout in terms of a dense grid street network.

### *Summary*

The statistical models presented in this section support two sets of findings. The first is that walk distance and the characteristics of the individual trip-maker are the primary determinants of the choice of BART access mode. This is true whether walking is compared to all non-walk alternatives collectively, or to specific alternatives such as driving or taking transit. A second finding is that the importance of these attributes in explaining walk mode choice can vary widely by BART station. As the results of Tables 4 and 5 suggest, using dummy variables to represent these station area effects doesn't go far enough in explaining which station area characteristics matter and which don't. We explore this issue in the next section.

## V. Determinants of BART Access Mode Share

This analysis examines the effect of various measures of station area physical design and urban form on transit access walk trips. The unit of analysis in this section is the station area, not, as in the previous section, the traveler. Station areas are defined as the area (or neighborhood) within one-half mile of each BART station. The principle method of analysis is linear regression. The dependent variable, walk mode share, was assembled from the 1992 BART Passenger Profile Survey. Independent variables were assembled from the 1990 U.S. Census, and through extensive on-site observation. As above, this analysis is limited to home-based trips.

### *Model Specification and Variables*

We hypothesize that the walk access trips to BART as a share of all access trips are a function of the average walk trip distance to a particular station; selected characteristics of each station such as parking capacity; selected socio-economic characteristics of each station area; the extent to which the local street system is pedestrian-oriented; and the mix of land uses in the station area:

Eq.2: Walk Mode share$_i$ = f[Average walk trip distance,
Station characteristics,
Station area socio-economic characteristics,
Station area street characteristics,
and Station area land uses]

These five characteristics were measured using 25 different variables:

1. The independent variable WALKDIST measures the weighted average distance from the centroid of each census tract (with portions located within ½ mile of each station) to the nearest BART station. The distance is measured as the shortest distance along the street. Based on the results of the prior analysis, we would expect WALKDIST to be negatively correlated with walk mode share.

Station Area Characteristics

2. The variable PARKING measures the number of parking spaces at each station. Stations with larger parking lots and more parking spaces are, we suspect, more attractive to drivers. Moreover, walkers may find it inconvenient to traverse large parking lots. We would therefore expect this variable to be negatively correlated with walk mode share.

3. The variable STAPARK is a 0/1 dummy variable indicating whether or not the parking capacity of a given station exceeds 100 cars. If it does, STAPARK is assigned a value of 1. As above, we would expect STAPARK to be negatively correlated with walk mode share.

Station Area Socioeconomic Characteristics

Aggregate socioeconomic data was collected from the 1990 U.S. Census for census tracts within one-half mile of each BART station. For those census tracts not wholly within one-half mile, values were pro-rated according to the share of census tract area within a half-mile radius. To the extent that the socio-economic characteristics of the station area (and not the traveler) affect walk mode share, we expect some or all of the following variables to be statistically significant determinants of walk mode share.

4-7. The variable HIGHSCH measures the share of the station area population (18+ years of age or older) who have completed high school but not college. The variable COLLEGE measures the share of the station area population that that attended college but did not receive a four-year degree. The variable BACHELOR measures the share of the station area population that attained a four-year college degree. And the variable GRADUATE measures the share of the station area population that attended college at the graduate or professional degree level.

8-11. The variable PROF measures the share of the station area population (16+ years of age or older) that is occupied in professional fields, including executive, administrative, managerial, professional specialty occupations, technicians and related support positions. The variable SERVICE measures the percentage of the station area population occupied in the service sector including sales, administrative support, clerical, and service occupations. The variable BLUECOL measures the percentage of the station area population occupied in blue collar trades, including precision production, craft, repair, machine operators, assemblers, inspectors, transportation, handlers, equipment cleaners, helpers, and laborers. And the variable OTHER measures the percentage of the station area population employed in miscellaneous positions including private household, protective service, and agriculture.

12. MEDINC is the (weighted average) median household income of the station area population. To the extent that walking activity in an area is sometimes presumed to be negatively related to area income, we would expect this variable to be negative.

13. MEDAGE is the (weighted average) median age of the station area.

14. VEHPER is the number of private vehicles per person. As a measure of area auto availability, we would expect it to be negatively correlated with walk mode share.

Station Area Street Characteristics and Design

The design of the station area street system creates both opportunities for and barriers to walking. Grid street patterns, complete sidewalk systems, and other pedestrian amenities should (theoretically, at least) encourage pedestrian access. Heavily trafficked arterials, close proximity to freeways and inadequate street crossings should deter it. We looked at four measures of station area street design:

15. ARTLEN measures the total length of all arterial streets (those wider than two travel lanes) within a one-half-mile radius of each BART station. To the extent that pedestrians perceive wide streets as a barrier to walking, or to the extent that arterials serve higher automobile volumes, ARTLEN should be negatively correlated with walk mode share.

16. GRID is a 0/1 dummy variable that indicates whether the station area street pattern resembles a grid pattern. Urban designers argue that grid pattern street systems are more "readable" at the street level, and thus more attractive to pedestrians. Accordingly, we hypothesize a positive relationship between the GRID variable and walk mode share.

17. The variable FWYINT measures the number of freeway interchanges within a one-half-mile radius of each station. Freeway interchanges are generally considered to be pedestrian barriers.

18. FWYPRX is a 0/1 dummy variable that indicates whether a freeway traverses the station area.

Station Area Land Use Mix

Pedestrian access is also likely to be affected by the type, density, and mix of land uses in a given station area. We looked at seven measures of station area land use:

19. The variable POPDEN measures the station area population density (in persons per acre). Density is a measure of the number of potential trip origins. Many urban designers also believe that density, by itself, encourages pedestrian traffic. For both reasons, we would hypothesize the relationship between station area population density and walk mode share to be positive.

20. The variable DWLDEN measures the housing density of each station area (in dwelling units per acre). It is an alternative to POPDEN.

21. The variable RETCNTR is an ordinal measure of the linear distance to the nearest retail center. Retail centers are defined as store clusters and include downtown shopping areas, shopping malls, and neighborhood shopping centers and are of pedestrian orientation. Auto-oriented strip shopping centers are not included. RETCNTR takes on a value of 3 if there is a retail center within 1/6 mile of the station; 2 if there is an activity center within 1/3 mile; 1 if there is a retail center within a half-mile; and 0 if there is no retail center within a half-mile. We hypothesize that RETCNTR and walk mode share are positively related.

22-23. RETAIL and OFFICE are 0/1 dummy variables that indicate whether retail land uses or office land uses (respectively) are the dominant land use within each station area.

24-25. MIXMED and MIXHI are 0/1 dummy variables indicating the land use diversity within a station area. MIXMED indicates a moderate mix of retail, residential, and other land uses within a station area. MIXHI indicates a high level of land use mixture. Urban designers hypothesize that a diverse mixture of land uses serves to attract pedestrian activity.

Table 7 presents summary statistics for each independent variable.

### *Model Results*

Multiple regression allows one to investigate one set of relationships while controlling for others. In this case, we are interested in identifying the effect of station area design and land use characteristics on walk access mode share, *controlling for station area socio-economic factors.* Initial regression model runs included all 34 BART station area. We subsequently removed five downtown stations from the dataset (Embarcadero, Montgomery, Powell, Civic Center, and 12th Street/Oakland) because walk access trips to those stations were so infrequent. Because population density and dwelling unit density are so highly correlated, we tested separate models using population density without dwelling unit density, and dwelling unit density without population density. The education and occupation variables were also highly correlated; we therefore selected the combination of education and occupation variables that maximized overall fit while minimizing multi-collinearity.

## Table 7: Summary Statistics for Station Area Variables

| Variable | | 34 Stations | | 29 Stations | |
|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Mean | Std. Dev. |
| *Trip characteristics* | | | | | |
| Share of trips originating from the home | HOMEB | 0.22 | 0.17 | 0.22 | 0.18 |
| Share of trips originating from work | WORKB | 0.47 | 0.26 | 0.42 | 0.23 |
| Share of trips originating from school | SCHOOLB | 0.36 | 0.26 | 0.32 | 0.25 |
| Weighted walk distance from station to origin | WALKDIS | 2,770 | 3,057 | 3,029 | 3,169 |
| *Population Characteristics* | | | | | |
| % with high school degree | HIGHSCH | 0.47 | 0.17 | 0.46 | 0.18 |
| % with some college | COLLEGE | 0.28 | 0.05 | 0.28 | 0.05 |
| % with college degree | BACHELOR | 0.17 | 0.09 | 0.16 | 0.09 |
| % with graduate degree | GRADUATE | 0.09 | 0.07 | 0.09 | 0.08 |
| % employed in professional, managerial, technical | PROF | 0.33 | 0.14 | 0.33 | 0.14 |
| % employedoyed in service, sales, clerical, administrative | SERVICE | 0.42 | 0.06 | 0.42 | 0.06 |
| % employedoyed in craft, repair, assembly, inspectors | BLUECOL | 0.21 | 0.08 | 0.22 | 0.09 |
| % employedoyed in protective service, agriculture, etc | OTHER | 0.04 | 0.02 | 0.04 | 0.02 |
| Median Household Income - weighted average | MEDINC | 31,134 | 14,999 | 32,315 | 15,491 |
| Median Age - weighted average | MEDAGE | 33.5 | 4.1 | 32.8 | 3.9 |
| Number of private vehicles per person | VEHPER | 0.90 | 0.06 | 0.91 | 0.06 |
| *Area Characteristics* | | | | | |
| Total length of arterials wider than two lanes | ARTLEN | 3.89 | 2.81 | 3.05 | 1.66 |
| Population density | POPDEN | 18.60 | 14.08 | 16.31 | 11.29 |
| Dwelling Unit density | DWLDEN | 8.89 | 8.18 | 7 | 4.53 |
| Number of parking spaces at each station | PARKING | 914 | 884 | 1,035 | 871 |
| Indicator of the existence of parking at the station | STAPARK | 0.68 | 0.48 | 0.77 | 0.43 |

Table 8 presents the results of the two "best" models of walk mode share; the first including population density, the second including dwelling unit density. The two models fit the data very well indeed, explaining 89% and 92%, respectively, of walk access mode share. The dwelling unit density model provides a slightly better overall goodness-of fit, however, the population density model includes one more statistically significant variable — distance to the nearest retail center. In general, the same variables were found to be statistically significant in both models. (Many of the proposed independent variables were not statistically significant, or else were multi-collinear with variables that were statistically significant).

Density (whether population density or dwelling unit density) is by far the most important explanatory variable, accounting for 50% to 60% of the variation in walk mode share. For every additional increment of population density (above the sample mean of 18.6 persons per acre), walk mode share increases by one percent. For every additional increment of dwelling unit density (above the sample mean of 8.8 units per acre), walk mode share increases by three percent. As expected, the availability of nearby retail activities is positively correlated with walk mode share. (However, this relationship is statistically significant only in the case of the population density model.) BART patrons are more likely to walk, it seems, if there are nearby stores.

Walk mode shares are higher for station areas inhabited by college graduates, but lower for station areas inhabited by blue-collar production workers. The positive relationship of income and walk mode share — although somewhat surprising and contrary to conventional wisdom regarding transit use — reflects the fact that BART is principally a commuter railroad that serves higher income suburban commuters.

As expected, the number of available parking spaces at a station is inversely related to walk mode share. We note, however, that the effect is not a particularly large one. The coefficient for the street grid dummy variable was found to be negative, suggesting that BART patrons are somewhat less likely to walk to BART from neighborhoods formed by rectilinear street patterns. This finding runs somewhat contrary to conventional urban design wisdom.

## VI. Combined Models

For the individual BART rider, walking distance is the primary determinant of access mode choice, followed by gender and car availability. At the level of the station area, density is the primary determinant of access mode share. Because they are based on different units of analysis — the individual traveler versus the station area — these two findings are odds with each other. To provide a fuller understanding of how individual and station area characteristics both affect access mode choice, we used the BART station of access to link traveler and station area characteristics. We then re-ran the three

**Table 8: Home-based BART Trips-Walk Access Share: Regression Model Results**

| Independent Variables | Population Density Model | | Dwelling Unit Density Model | |
|---|---|---|---|---|
| | Coefficient | t-statistic | Coefficient | t-statistic |
| *Station Area Demographics* | | | | |
| GRADUATE | Not significant | | 0.776479 | 4.552 |
| BLUECOLLAR | -0.863815 | -5.628 | Not significant | |
| MEDINCOME | -0.000005 | -4.854 | -0.000004 | -3.664 |
| *BART Station Characteristics* | | | | |
| PARKING | -0.000053 | -2.977 | -0.000046 | -3.079 |
| *Station Area Characteristics* | | | | |
| GRID | -0.114222 | -3.04 | -0.098439 | -3.085 |
| POPDEN | 0.009794 | 7.614 | Not entered | |
| DWELDEN | Not entered | | 0.031622 | 11.231 |
| RETCNTER | -0.037439 | -3.044 | n/s | |
| Constant | 0.641527 | 7.341 | 0.17877 | 3.301 |
| R-Squared | 0.894 | | 0.921 | |

logit models of access mode choice presented in Part IV, this time including various station area land use and urban form measures. The results of this combined analysis are presented in Table 9.

Compared to the initial model results (as presented in Table 4), the combined analysis provides only a minor improvement in overall predictive accuracy. The combined walk vs. non-walk , walk vs. transit, and walk vs. drive models correctly predict 57.8%, 85.7%, and 74.3%, respectively, of access mode choices (vs. 58%, 91.9%, and 74.3% for the original models). Beyond issues of predictive accuracy, the results of the combined models provide a much more sophisticated understanding of why travelers walk to BART. For example, controlling for the personal and trip characteristics of individual BART riders, station area population and dwelling unit density — the two most significant variables in the station area analysis presented in Part V — turn out not to be statistically significant. Density itself neither encourages or discourages individuals to walk to BART; rather, it is the shorter walk-trip lengths associated with intense station area development that encourage walking. As in the original models, the higher the individual level of income and car ownership, the lower the probability of walking. By contrast, the availability of bus transit (as an access mode to BART) does not seem to encourage its use.

Two station area characteristics that do seem to affect walking — and defy our ability to explain why — are income and age. All else being equal, higher levels of station area income are associated with a lower probability that individuals will walk to BART. Conversely, the older the age of the station area population, the more likely it is that travelers will access BART by walking.

The combined models also provide new insights into the effects of station area urban design on walking behavior:

- The greater the number and length of major arterials within a BART station area, the less likely travelers are to walk to that station. This finding is consistent with the view that wide and/or busy arterials function as pedestrian barriers.
- Instead of encouraging travelers to walk to BART, a grid system of streets has the opposite effect. Likewise, a very high degree of land use mixture within a station area seems to discourage, not encourage, pedestrian access.
- Travelers are less likely to walk to BART stations if they are traversed by freeways.
- Travelers are much more likely to walk to BART stations surrounded by retail activities. The nearby presence of office activities, however, has no effect on walk preferences.
- BART parking lots serve as barriers to walking, but the effect is not linear. Larger parking lots don't discourage walking any more than smaller ones.

**Table 9. Combined Logit Model Of BART Access Mode Choice**

| | **Walk vs. Non-Walk Model** | | **Walk vs. Transit Model** | | **Walk vs. Auto Model** | |
|---|---|---|---|---|---|---|
| **Independent Variable** | Coefficient | Significance level | Coefficient | Significance level | Coefficient | Significance level |
| *Trip Characteristics* | | | | | | |
| DISTANCE | -1.3024 | 0.0001 | -0.8582 | 0.0001 | -0.9625 | 0.0001 |
| DBLOCKS | 0.0132 | 0.0075 | 0.0232 | 0.0017 | | Not significant |
| WALK-EGRESS | | Not significant | | Not significant | | Not significant |
| BIKE-EGRESS | | Not significant | | Not significant | | Not significant |
| AUTO-EGRESS | | Not significant | | Not significant | | Not significant |
| TRANSIT-EGRESS | | Not significant | | Not significant | | Not significant |
| PURHOME | | Not significant | | Not significant | | Not significant |
| PURWORK | -0.2247 | 0.0121 | -0.1954 | 0.0679 | -0.3079 | 0.0058 |
| PURSCHL | -0.3447 | 0.0049 | -0.3431 | 0.0184 | | Not significant |
| PURSHOP | | Not significant | | Not significant | 0.5502 | 0.021 |
| CARAVAIL | -0.4474 | 0.0001 | | Not significant | -0.8638 | 0.0001 |
| TRANSAVAIL | | Not significant | | Not significant | | Not significant |
| *Traveler Characteristics* | | | | | | |
| EWHITE | | Not significant | | Not significant | | Not significant |
| EBLACK | -0.3071 | 0.005 | -0.4451 | 0.0005 | | Not significant |
| EASIAN | -0.2598 | 0.0147 | -0.3237 | 0.0092 | | Not significant |
| GENDER | 0.4654 | 0.0001 | 0.3678 | 0.0001 | 0.6122 | 0.0001 |
| AGE13 | | Not significant | | Not significant | 0.7978 | 0.099 |
| AGE18 | | Not significant | 0.4582 | 0.0957 | | Not significant |
| AGE25 | | Not significant | | Not significant | | Not significant |
| AGE35 | | Not significant | | Not significant | | Not significant |
| AGE45 | | Not significant | | Not significant | -0.5154 | 0.0993 |
| AGE65 | -0.8924 | 0.002 | -0.9119 | 0.0044 | -0.9881 | 0.0064 |
| INC15 | | Not significant | | Not significant | | Not significant |
| INC30 | | Not significant | 0.2148 | 0.0437 | -0.2765 | 0.013 |
| INC45 | | Not significant | | Not significant | -0.4558 | 0.0002 |
| INC60 | -0.2416 | 0.0382 | | Not significant | -0.7766 | 0.0001 |
| INC75 | -0.4738 | 0.0001 | | Not significant | -1.0669 | 0.0001 |
| *Station Area Demographics* | | | | | | |
| HIGHSCH | | Not significant | 20.8192 | 0.0929 | | Not significant |
| COLLEGE | | Not significant | 28.3899 | 0.0332 | | Not significant |
| BACHELOR | | Not significant | 23.4747 | 0.0748 | | Not significant |
| GRADUATE | | Not significant | 30.4602 | 0.0345 | | Not significant |
| PROF | | Not significant | -27.378 | 0.0247 | | Not significant |
| SERVICE | | Not significant | | Not significant | | Not significant |
| BLUECOL | | Not significant | -28.8451 | 0.0785 | | Not significant |
| OTHER | | Not significant | -30.3235 | 0.008 | | Not significant |
| MEDINC | -0.00008 | 0.0001 | -0.00009 | 0.0001 | -0.00007 | 0.0001 |
| MEDAGE | 0.0687 | 0.0374 | 0.0807 | 0.0488 | | Not significant |
| VEHPER | -2.193 | 0.0335 | -5.0627 | 0.0001 | | Not significant |
| *Station Area Characteristics* | | | | | | |
| POPDEN | | Not significant | | Not significant | | Not significant |
| DWLDEN | | Not significant | | Not significant | | Not significant |
| ARTLEN | -0.1713 | 0.0001 | -0.3004 | 0.0001 | | Not significant |
| PARKING | | Not significant | | Not significant | | Not significant |
| STAPARK | -0.5919 | 0.0031 | | Not significant | -1.2002 | 0.0001 |
| Distance to Nearest Activity Center | | Not significant | | Not significant | | Not significant |
| Grid Street Layout Indicator (0/1) | -0.6152 | 0.0123 | -0.9495 | 0.003 | -0.7421 | 0.0113 |
| Number of Freeway Interchanges in Area | | Not significant | | Not significant | 0.2614 | 0.0606 |
| Freeway Proximity Indicator (0/1) | -0.4867 | 0.0099 | -0.6687 | 0.0024 | -0.7782 | 0.0011 |
| Retail Dominant Land Use (0/1) | 0.8927 | 0.0001 | 1.2951 | 0.0001 | 0.8857 | 0.0002 |
| Office Dominant Land Use (0/1) | | Not significant | | Not significant | | Not significant |
| Medium Level of Land Use Mixture (0/1) | | Not significant | | Not significant | | Not significant |
| High Level of Land Use Mixture (0/1) | -0.726 | 0.0247 | -1.2769 | 0.0012 | -0.7508 | 0.0507 |
| Weighted Straight Line Walking Distance from Area Population Centroid to Station | 0.00005 | 0.0809 | | Not significant | 0.00006 | 0.081 |
| Constant | | | | | | |
| % correctly predicted | 57.8% | | 85.7% | | 74.3% | |

## VII. Summary of Findings and Policy Implications

Access to transit and mode choice in general has traditionally focused on the transit mode as the primary alternate to driving. This study has diverged in methodology and looked at the walk mode and the determinants to walking, particularly in regard to access to rail transit stations. A series of analysis was conducted — first, of individual characteristics, followed by station area characteristics, and concluding with a combined analysis.

Analysis of a large individual data set of home-based trips to origin BART stations reveal the following significant findings:

- Walking distance is the most significant factor in the choice to walk.

  The decision to walk to BART is influenced much more by individual characteristics than by urban design or station area characteristics.
- All else being equal, men are much more likely to walk to BART than women.
- Station area population and dwelling unit density — two variables significantly associated with higher walk mode shares — are insignificant considerations in the mode choice decision of individual travelers.
- All else being equal, BART stations in office-dominated downtown areas are much less attractive to walkers.
- BART stations in retail-oriented environments are more attractive to walkers.
- All else being equal, travelers with higher incomes and levels of auto availability are much less likely to walk to a BART station than to drive.
- All else being equal, income plays a lesser role in the walk-to-BART vs. take-transit choice than ethnicity, age, and egress distance.

### *Planning Implications*

These findings provide important new information for transit planners and advocates of transit-oriented development. They suggest that density and urban design by themselves do relatively little to increase the likelihood of walking to transit instead of driving. Instead, the primary factors that explain access mode preferences are gender, age, auto availability, income, and — far more than any other single factor — walking distance. Thus, the primary argument for developing higher-density housing near transit is to increase the pool of potential BART riders. To the extent that transit-oriented development results in a loss of adjacent parking, it could also result in an overall loss in transit ridership.

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